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TECHNICAL REPORT NO. 10528

GLASS FIBER REINFORCED PLASTIC TIRES FOR THE
MARGINAL TERRAIN VEHICLE (U)

FINAL REPORT



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by James C. Hood
OWENS-CORNING FIBERGLAS CORP.

TACOM

Date: April, 1969

Contract No. DAAE 07-67-C-3853

VEHICULAR COMPONENTS & MATERIALS LABORATORY
U.S. ARMY TANK AUTOMOTIVE COMMAND Warren, Michigan

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FOR THE
MARGINAL TERRAIN VEHICLE

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JAMES C. HOOD
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U. S. Army Tank - Automotive Command
Warren, Michigan 48090

Contract No. DAAE 07-67-C-3853

Owens-Corning Fiberglas Corporation
Technical Center
Granville, Ohio 43023

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ABSTRACT

The program objective was to develop and fabricate glass fiber reinforced plastic (GFRP) tires for use on the Marginal Terrain Vehicle. These tires were to have been non-pneumatic, hence were to have provided a tire having post-damage "get home" capability.

Several configurations of tire were fabricated for test; none was found that yielded a tire with load/deflection characteristics that compared favorably with rubber pneumatic tires nor that would support appropriate loads without carcass failure.

FOREWORD

This report covers the work performed by Owens-Corning Fiberglas Corporation, Granville, Ohio, under U. S. Army Tank - Automotive Command Contract No. DAAE 07-67-C-3853, during the period March, 1967 through September, 1968.

The contract was initiated by the Rubber Products Branch of Materials Division under Request No. PR 67-62. The Contract was under the technical direction of Mr. Roger Kirk (AMSTA-BMR) of the Rubber Products Branch.

The program was conducted by the Reinforced Plastics Market Development Department of the Owens-Corning Fiberglas Corporation Technical Center, Granville, Ohio. Mr. James C. Hood was the principal investigator, assisted mainly by Messrs. P. Douglas Lyle, Brent Augenstein, and Evariste Charron.

I.

INTRODUCTION

About four years ago, Owens-Corning started in-house research directed toward proving the feasibility of a filament wound, glass fiber reinforced plastic (GFRP) pressureless tire. This work was started after we read Item 2178 of VOLUME III, INVENTIONS WANTED BY THE ARMED FORCES AND OTHER GOVERNMENT AGENCIES. The document had been issued by the U. S. Department of Commerce in November, 1963. Item 2178 called for, " - - - a tire which maintains or exceeds present wear and ride characteristics and is impossible to deflate. It is not necessary to limit research to present rubber tire concepts. "

Through considerable in-house effort, a GFRP pressureless tire concept was developed and a full scale feasibility model of a Jeep-type tire was fabricated. The concept and model were presented to ATAC technical personnel in 1966.

During this presentation, Owens-Corning became cognizant of the pneumatic rubber tire used on the Marginal Terrain Vehicle. After study, we believed that the tire could be developed in a GFRP pressureless configuration, and that it might offer the same operational advantages envisioned for the Jeep-type tire - i. e., post-damage "get home" capability. This opinion was reinforced by the promising load/deflection performance of 17 inch diameter GFRP filament wound cylinders that were tested in-house before delivery to ATAC on Contract No. DAAE 07-67-M-0852 (1966). The cylinders were made for test as floating supports in the LVAX vehicle.

A proposal to develop this tire was submitted to ATAC. Contract No. DAAE 07-67-C-3853 arose out of this proposal.

II.

PROGRAM OBJECT

The object of the program was to develop and fabricate 24" diameter x 21" wide glass fiber reinforced plastic (GFRP) tires for possible use on the Marginal Terrain Vehicle (MTV). Since these GFRP tires would not rely on air pressure to support a load, in use they were to have provided a tire having post-damage "get home" capability.

III.

SUMMARY

The glass fiber reinforced plastic (GFRP) tire for the MTV consisted of an E-glass 182 style glass fabric/epoxy resin laminate. The outside surface was covered, by bonding, with rubber.

The carcass was molded in transverse halves which were then bonded over a stiffener ring to form the MTV tire. Molding techniques involved use of a plastic male mold, tailored glass fiber fabric socks, a vacuum injection molding process, and a vacuum bag and autoclave layup process.

Three carcasses were made in attempts to produce a tire that would have a spring constant of 3000 pounds per foot and would reliably support a nominal service load of 300 pounds. Although the third carcass met the nominal goals, it demonstrated no margin of safety in load supporting characteristics.

Two model MTV tires were fabricated, equipped with axles and delivered to ATAC.

IV.

CONCLUSIONS

A glass fiber reinforced plastic shell of the configuration tried in this program was proven to be unsuitable for use as an MTV tire. In general terms the problem is that a shell of double curvature and made of a relatively stiff material will not take a large deflection without buckling. Thick shells were found to be much too rigid to meet the target load-deflection characteristics. Thin shells of the same configuration proved unsuitable because destructive buckling would occur at relatively low loads and deflections.

V.

RECOMMENDATIONS

Determine feasibility of a low vulnerability pressureless MTV tire consisting of:

- A. A rubber covered filament wound GFRP cylinder attached to the axle by a thick-walled rubber plug on each end. The ability of filament wound cylinders to withstand the rigors of operation on the MTV was shown by the ATAC test of 17 inch cylinders on the LVAX* and in laboratory impact and load deflection tests**. These test cylinders were supplied to ATAC on Contract DAAE 07-67-M-0852 (1966).
- B. A shell slit into semi-independent load bearing units to provide flexibility. The slit shell would be covered with a layer of rubber to preserve buoyancy. This concept was demonstrated by Owens-Corning on a conventionally shaped 7.00 x 16 vehicle tire under ATAC Contract No. DAAE 07-67-C-4319 (1967).

*ATAC Systems Evaluation Branch report dated July 23, 1967

**ATAC Vehicles Components and Materials Laboratory Report
No. 9651 (F) dated June 19, 1967

VI.

PROGRAM DISCUSSION

A. Material Selection

The MTV tire was to consist of a GFRP pressureless carcass, the outside surface of which was to be covered, by bonding, with rubber. The carcass was to be an E-glass 182 style glass fabric/epoxy resin laminate.

B. Tire Design

The tire carcass was designed to be molded in transverse halves. These halves were then to be bonded together over a stiffener ring; the assembled and bonded tire was then to be placed on a steel axle. The tire/axle assembly is shown on Owens-Corning Fiberglas Drawing 10-5-66-1 (Appendix I). The axle design was subsequently modified as shown on Owens-Corning Fiberglas Drawing D-5367, Revision 1 (Appendix I). The final tire/axle assembly is shown on Owens-Corning Fiberglas Drawing 2-2-68-1 (Appendix I).

C. Fabrication Process

1. Mold

A plastic (epoxy) male mold was designed and built. It was cast in a female wooden pattern and was designed to produce one transverse tire carcass half. The mold (covered with a glass fabric sock) is shown in Figure 1.

2. Fabric Tailoring

Considerable time was spent developing an acceptable method to tailor the glass fabric to fit the plastic mold. Three dimensional weaving was ruled out because of high unit cost. After consultations with a manufacturer of glass fabric protective apparel, and because of the unique application, the glass fabric sock was developed by the cut-and-try method. A pattern was developed for a segment that would cover one-sixth of the mold. Six identical glass fabric segments were made from the pattern. These six segments were sewn together by machine to make a

single ply sock. The pattern, sewn glass fabric segments and sewing machine are shown in Figure 2. Figure 1 shows the finished sock on the mold.

3. Molding Technique

A vacuum injection system was used for resin impregnation of the dry fabric on the plastic carcass mold. This process used a Teflon coated curved steel plate as a model mold.

The technique involved laying up the appropriate number of glass fabric plies on the mold; covering the fabric lay-up with a tailored, heat-sealed PVA* vacuum bag; placing the mold and lay-up in an autoclave (see Figure 1); and forcing liquid resin (under pressure) through the wall of the autoclave into the vacuum bag and throughout the fabric.

The technique worked well on the curved plate model, producing a sound, void-free laminate. However, void-free laminates could not be produced on the actual tire mold, presumably because the plastic mold was not impervious to air.

A collapsible mandrel was built for molding the GFRP stiffener rings. The rings were made by saturating two inch wide HG 64**glass fiber tape with epoxy resin and winding the saturated tape on a mandrel. The composite was cured in an oven; the mandrel was collapsed to release the cured ring.

D. Fabrication Procedure

1. Carcass #1

Carcass #1 was made with eight plies of 182 style fabric. The halves were trimmed, beveled and bonded together over a .075" thick stiffener ring and the splice area overwrapped with four plies of HG 64 tape. This part was found to be much too rigid, and failed under load at a very small deflection (less than 0.5").

*polyvinyl alcohol

**Hess Goldsmith #64

2. Carcass #2

Carcass #2 was made with five plies of 182 style fabric which gave a laminate thickness of 0.080" - 0.085". The stiffener ring and overwrap were approximately the same as for Carcass #1. Carcass #2 was loaded between two flat plates and supported about 1900 pounds at a deflection of one inch on the diameter. The carcass was loaded in two places and both times exhibited a progressive laminate failure from one inch to three inch deflection while sustaining 2500 to 2700 pound loads.

3. Carcass #3

Carcass #3 was made with two plies of 182 style fabric. The halves were trimmed, beveled and bonded together over a three ply HG 64 tape stiffener ring with a one ply overwrap. When loaded between flat plates this carcass supported only 300 pounds at a deflection of two inches on the diameter. A large area of the carcass buckled inward under this load. The part returned to its original shape when unloaded, but the laminate had failed at several points around the edges of the buckle.

4. Carcasses #4 and #5

The design details for the two tire assemblies delivered are shown in Owens-Corning Fiberglas Drawing 2-2-68-1 (Appendix I). This drawing incorporates design changes generated in making carcasses #1 through #3, and presents necessary design details not shown in Owens-Corning Fiberglas Drawing 10-5-66-1.

Carcasses #4 and #5 were made with three plies of 182 style fabric. The halves were trimmed, beveled and bonded together over a two ply HG 64 tape stiffener ring with a one ply overwrap. Difficulty was experienced attempting to apply the rubber to the GFRP carcass. Several carcasses were locally

collapsed by the unexpectedly high shrinkage of the nylon cure tape that was wrapped over the rubber-fitted carcass for curing in 300° F steam. The problem was solved by placing two cellular expansion cushions between the rubber fitted carcass and the nylon cure tape.

Carcasses #4 and #5 were made, assembled with axles and delivered to ATAC in compliance with the Contract. These assemblies were not tested in any way before delivery. Figures 3 and 4 show several views of the delivered assemblies.

VII.

ILLUSTRATIONS

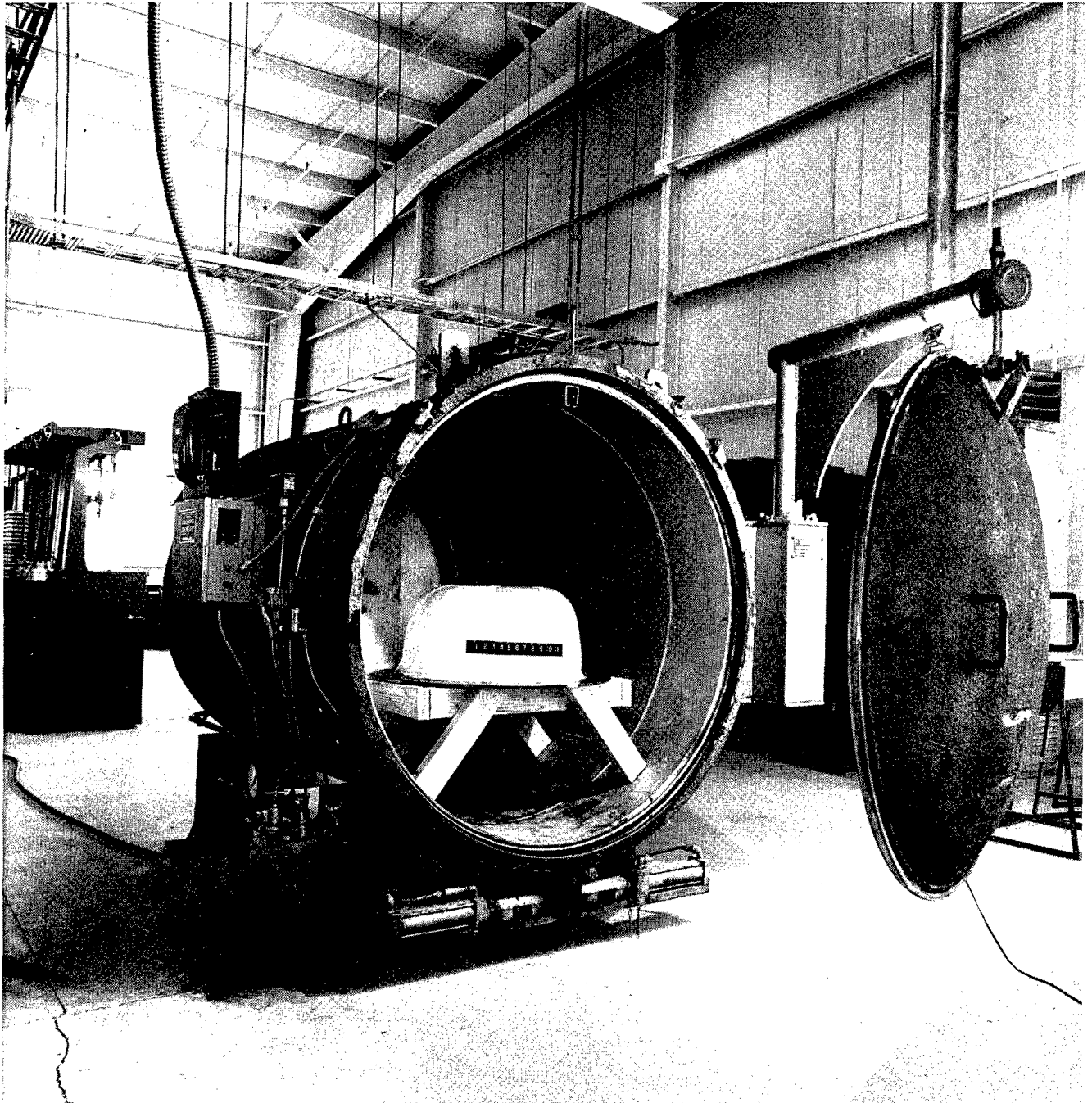


Figure 1. Autoclave, Mold and Tailored
Glass Fiber Sock

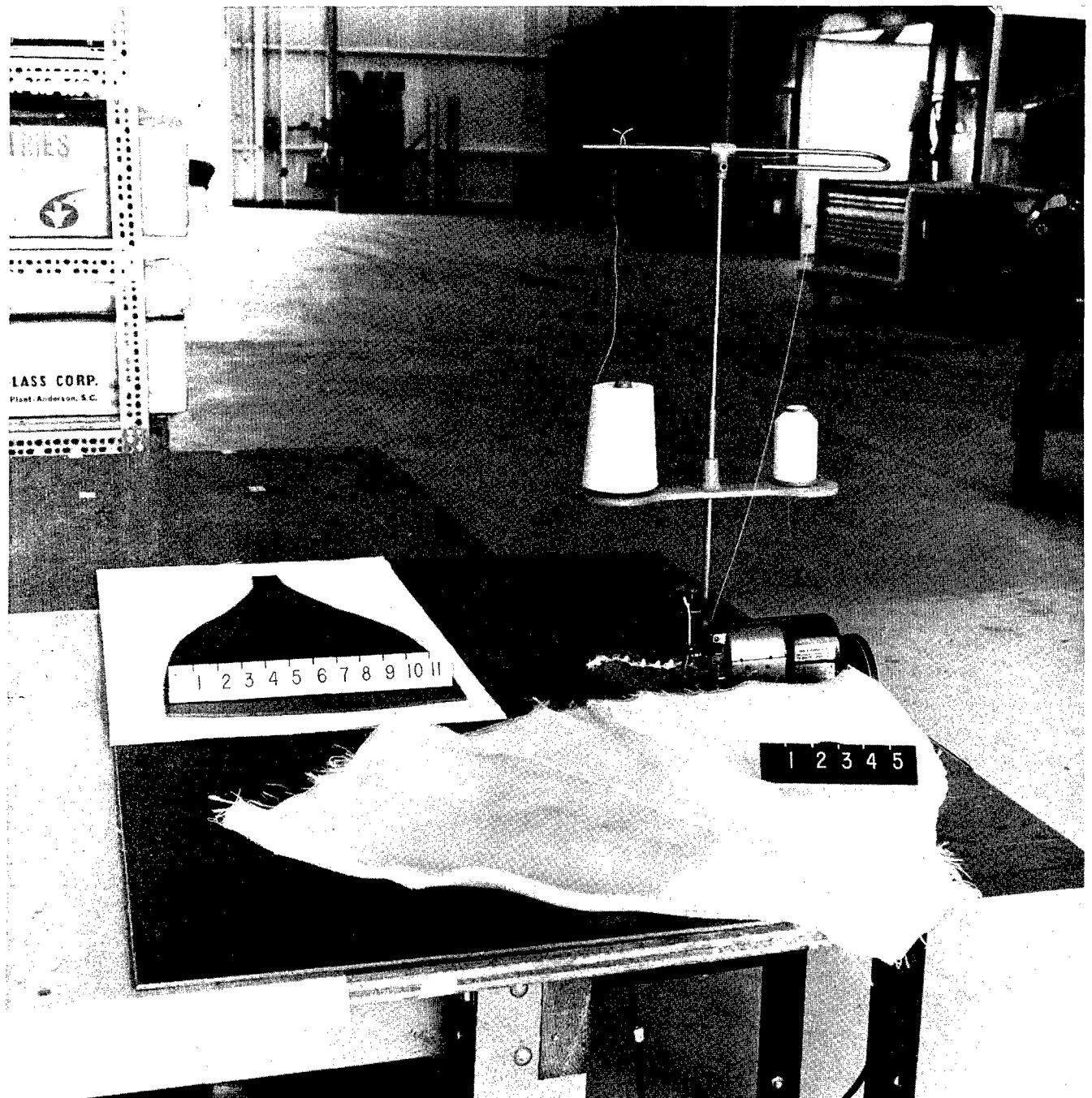
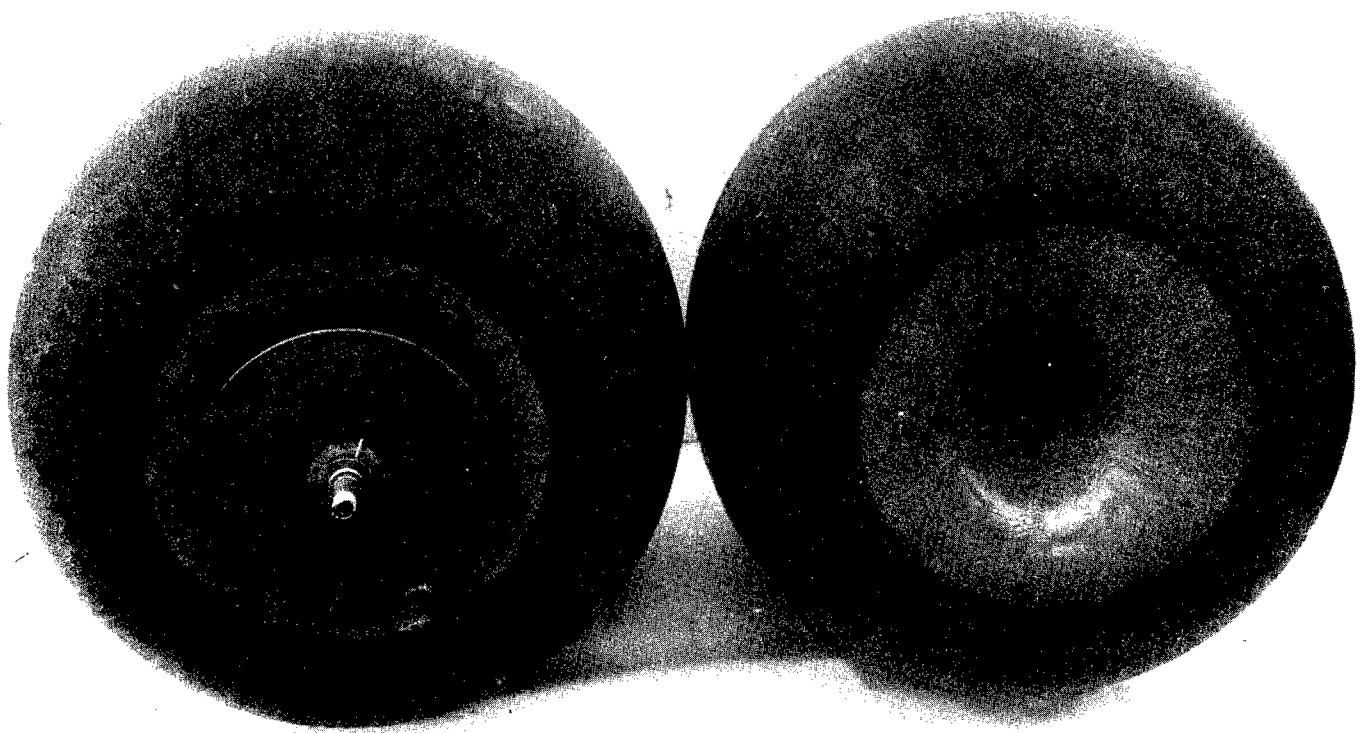


Figure 2. Pattern, Glass Fabric Segments and Sewing Machine



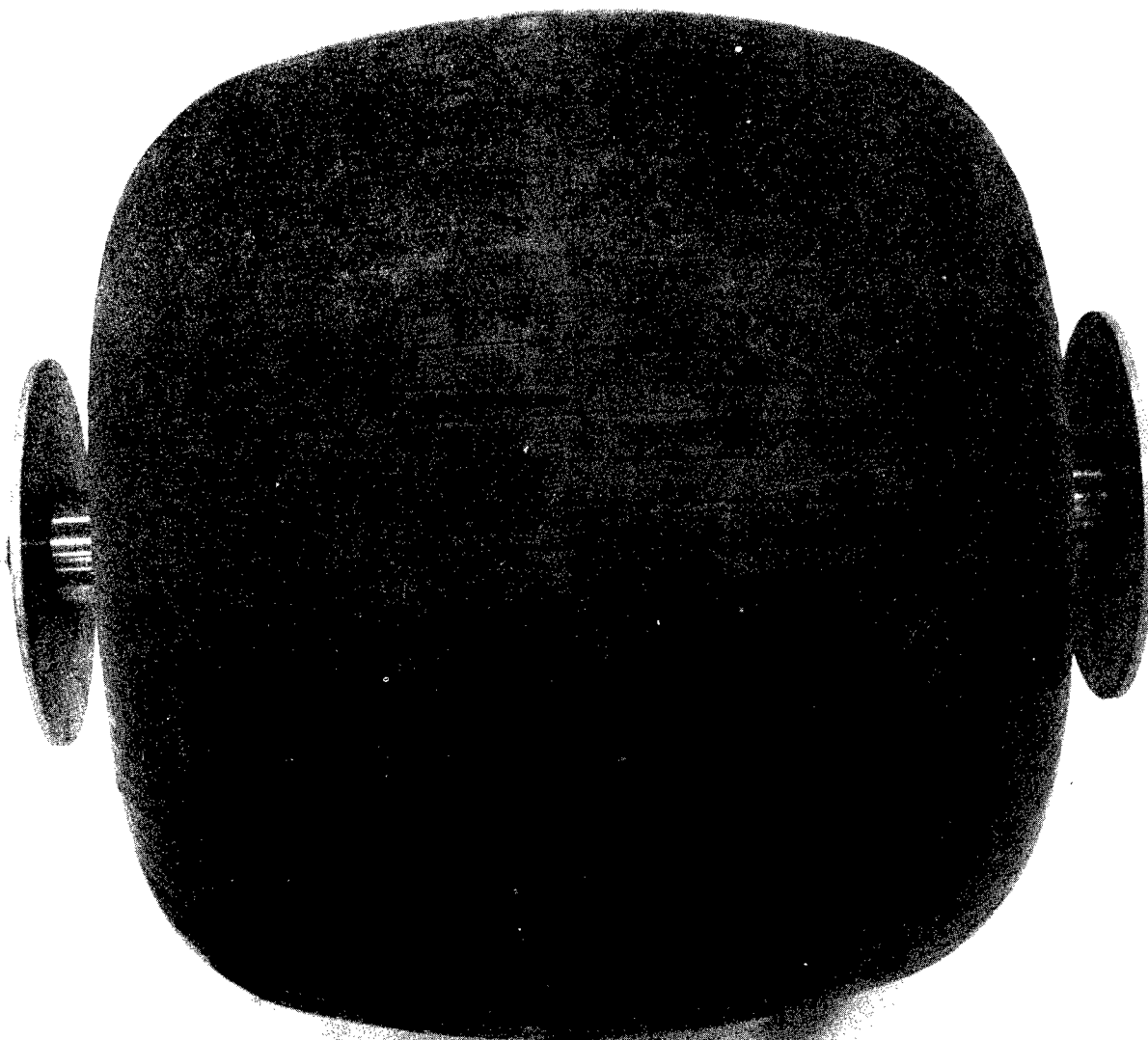
U.S. ARMY TANK-AUTOMOTIVE COMMAND

Neg. No. S20-P-2408-1/TACOM-69 **Date** 5 February 69

Glass Fiber Reinforced Plastic (GFRP) Non-Pneumatic
Tire For MTV. 1. Front View Of GFRP Non-Pneumatic Tire
For MTV (24" x 21") Mounted On Hub Assembly.



Figure 3. Rubber-Fitted Glass Fiber Reinforced
Plastic Tire and Axle Assemblies



U.S. ARMY TANK-AUTOMOTIVE COMMAND

Neg. No. 820-P-2408-2/TACOM-69 **Date** 5 February 69

Glass Fiber Reinforced Plastic (GFRP) Non-Pneumatic
Tires For MTV. 1. End View Of Mounted And Unmounted
Tiers.



Figure 4. Rubber-Fitted Glass Fiber Reinforced Plastic
Tire and Axle Assembly.

APPENDIX I

DRAWINGS

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13. ABSTRACT The program objective was to develop and fabricate glass fiber reinforced plastic (GFRP) tires for use on the Marginal Terrain Vehicle. These tires were to have been non-pneumatic, hence were to have provided a tire having post-damage "get home" capabilities. Several configurations of tires were fabricated for test; none was found that yielded a tire with load/deflection characteristics that compared favorably with rubber pneumatic tires nor that would support appropriate loads without carcass failure.			

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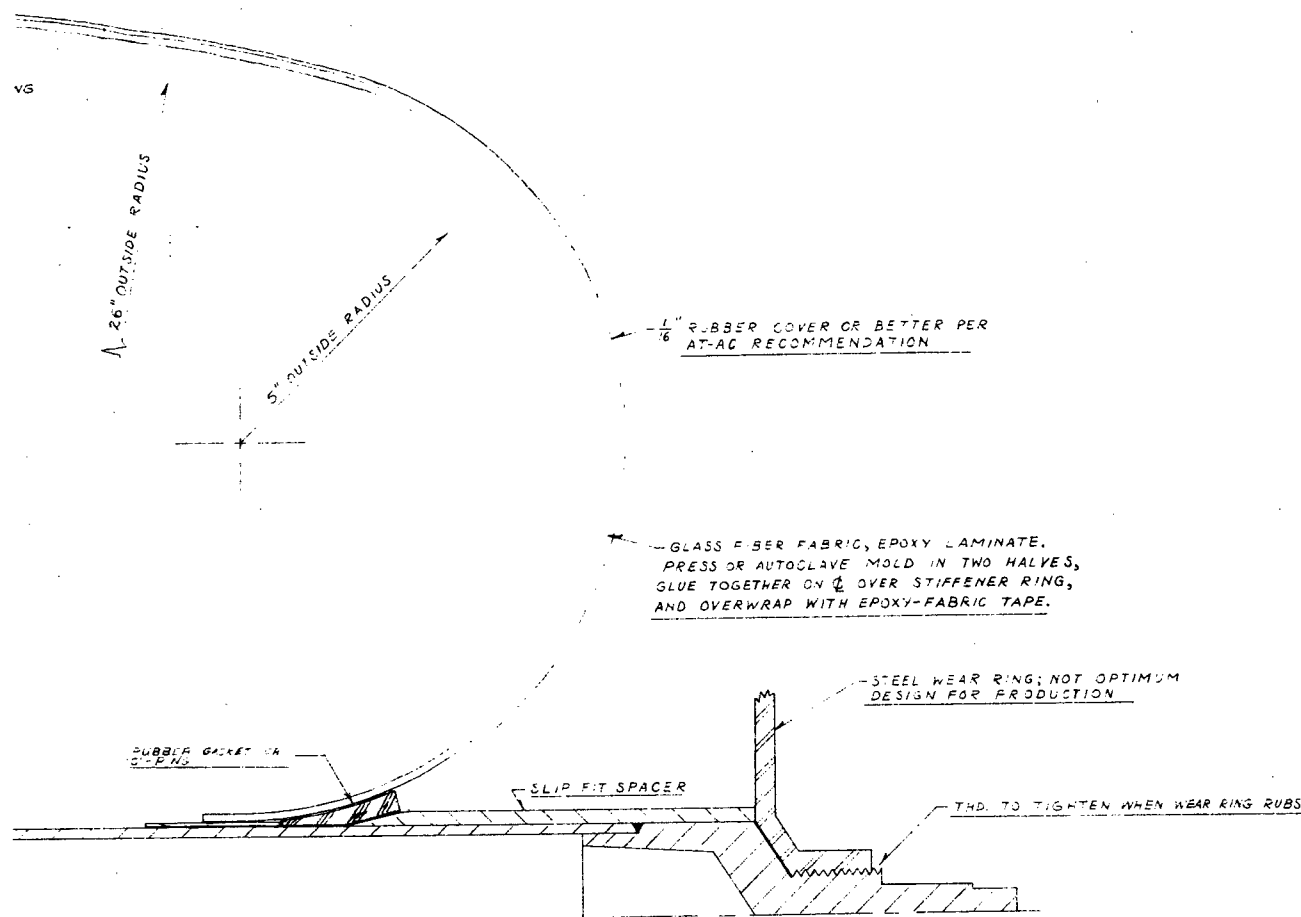
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THIS MATERIAL LIST FOR ONE DETAIL ONLY				
DET.	ITEM	REQ.	MATERIAL	WT



- 1/16" RUBBER COVER OR BETTER PER
AT-AC RECOMMENDATION

GLASS FIBER FABRIC, EPOXY LAMINATE.
PRESS OR AUTOCLAVE MOLD IN TWO HALVES,
GLUE TOGETHER ON $\frac{1}{2}$ OVER STIFFENER RING,
AND OVERWRAP WITH EPOXY-FABRIC TAPE.

- STEEL WEAR RING; NOT OPTIMUM DESIGN FOR PRODUCTION

- THD. TO TIGHTEN WHEN WEAR RING RUBS

NOTE: 1. TIRE SIZE 24 DIA. X 21" LONG X 2 1/2" HOLE
2. AXLE ASSY. TO FIT LVAX-1; DWG. DTA 162477

2. AXLE ASSY. TO FIT LVAX-1; DWG. DTA 162477

DATE	BY	CHK.	REV.	DESCRIPTION	THE FOLLOWING INDICATES BY DUPLICATES MUST BE NOTED FOLLOWING ANY REVISION	OWENS-CORNING FIBERGLAS CORPORATION TECHNICAL CENTER GRANVILLE, OHIO	ROAD WHEEL ASS'Y.	DATE 10-5-66 SCALE FULL	DWG. NO. 10-5-66-1	REVISION
					ISSUED TO	LOCATION		DRAWN J. HOOD	CHECKED	
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ROAD WHEEL ASS'Y.

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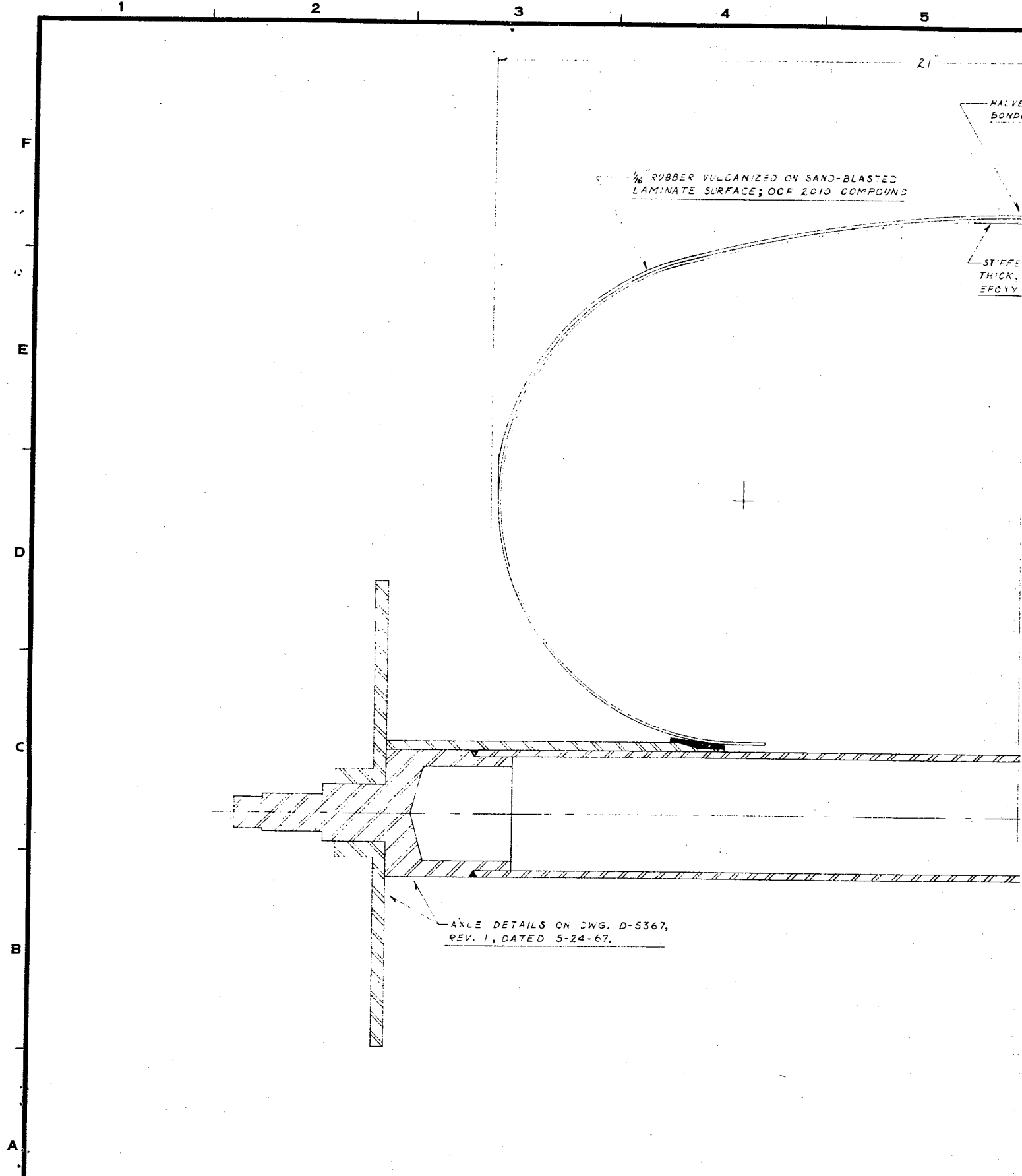
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THIS MATERIAL LIST FOR ONE DETAIL ONLY				
DET.	ITEM	REQ.	MATERIAL	WT.

—HALVES BUTTED ON \downarrow , EPOXY
BONDED OVER STIFFENER

-EPOXY LAMINATE OVERWRAP (NOT SHOWN),
2"x APPROX. 0.012", 1 PLY HG64 GLASS TAPE

—STIFFENER RING, 2' x APPROX. 0.025"
THICK, 2 PLY 4664 GLASS TAPE,
EPOXY RESIN

$$V \approx 5 \frac{13}{16} \text{ INCH RADIUS}$$

$4\frac{3}{10}$ RADIUS

— 3/64 EPOXY LAMINATE,
3 PLY 182 GLASS FABRIC,
INJECTION MOLDED IN AUTOCLAVE

-WEAR RING

-RUBBER GASKET VULC. ON
SPACER AND MACHINED

SLIP FIT SPACER

NOTE: 1. NOMINAL TIRE SIZE, 24" DIA x 21" LONG x 2 1/2" HOLE.
2. TIRE AND AXLE ASS'Y TO FIT LVAX-1 VEHICLE.

BY	CHK.	REV.	DESCRIPTION	THE FOLLOWING LISTINGS OF SUPPLIERS SHALL BE APPROVED FOLLOWING ANY REVISION		OWENS-CORNING FIBERGLAS CORPORATION TECHNICAL CENTER GRANVILLE, OHIO		ROAD WHEEL ASS'Y.		DATE: 2-2-68	SCALE: FULL	DWG. NO.	REVISION
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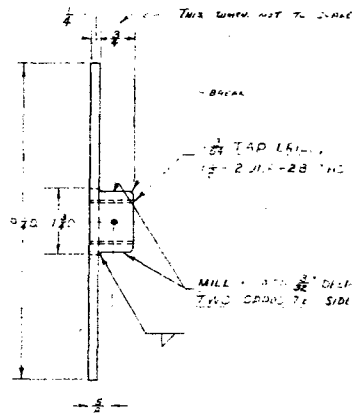
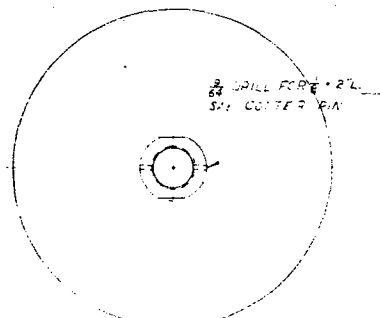
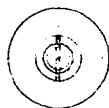
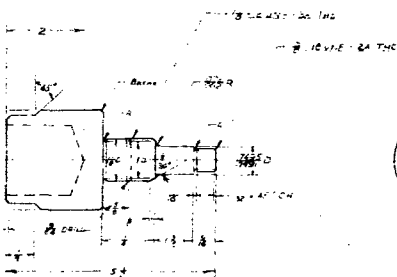
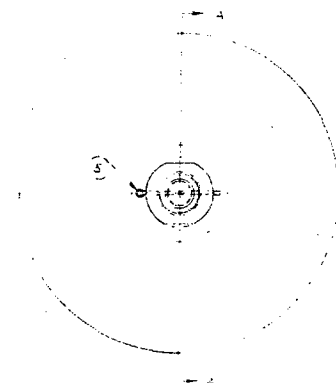
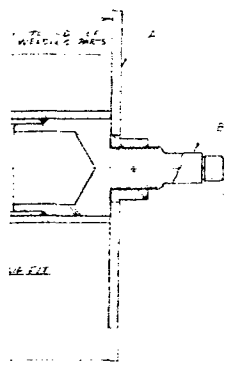
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DET.	ITEM	REQ.	MATERIAL	
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B	2	2	END FITTING - 4140 ALLOY, BAR STOCK	
C	3	1	AXLE TUBE - 4130 ALLOY, STD TUBING	
D	4	2	SLIP SPACER - 1018 STD TUBING	
	5	2	10-24 - SAE STD TAPER PIN	



B END FITTING

A WEAR RING
1045 CR EQUIV.

**OWENS-CORNING
FIBERGLAS**
CORPORATION
TECHNICAL CENTER
GRANVILLE, OHIO

AXLE FOR TIRE, MTV

DATE 5-29-67 SCALE HALF
DRAWN BY J. J. CHECKED BY J. J.
APPROVED BY J. J.

DWG. NO.
D-5367

REVISION
1

6

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7

8

FOLD DOWN

9

10